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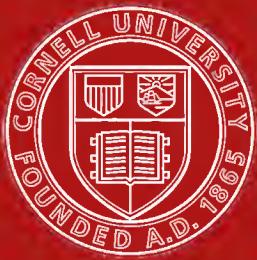
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The blackened rocks of the Nile cataract



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MINISTRY OF FINANCE

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# THE BLACKENED ROCKS OF THE NILE CATARACTS

AND OF

## THE EGYPTIAN DESERTS

by

A. LUCAS

*Chief Chemist, Survey Department Laboratory, Cairo.*



CAIRO:  
NATIONAL PRINTING DEPARTMENT  
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# THE BLACKENED ROCKS OF THE NILE CATARACTS AND OF THE EGYPTIAN DESERTS.

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The writer was led in the first instance to take up the study of this subject by having his attention drawn to some specimens of crystalline rock in the Cairo Geological Museum, which showed a peculiar black polished film on the outer surface.

Of the specimens one was a coarse-grained red granite (<sup>1</sup>) from the First, or Aswan, Cataract of the Nile, and the others were a fine-grained red granite (<sup>1</sup>), a basalt (<sup>1</sup>) and a dolerite (<sup>2</sup>) respectively, all from the Second Cataract, above Wadi-Halfa.

Two visits were subsequently made to Aswan at a time of the year (<sup>3</sup>) when the river down-stream of the new dam was at its lowest level and when the rocks in the river channel were most exposed. Under these conditions the intense jet-black colour of the rocks forms one of the most noticeable features of the cataract area. The smaller rocks are entirely black, shine brilliantly, and have the general appearance of masses of coal or blocks of pitch, while the larger rocks show a broad band of polished black immediately above the water level.

This remarkable phenomenon has been commented on by many different writers and the following references may be quoted : — “The granite rocks at the Cataract of Aswan have a very thin, dark-black, shining surface-coating which gives them the appearance of having been pitched.” (<sup>4</sup>)

“Les rochers qui sont baignés une partie de l’année par les eaux du Nil sont quelquefois revêtus à leur extérieur d’une espèce d’enduit noir lisse et brillant.” (<sup>5</sup>)

“Lorsqu’on parcourt en barque les mille méandres de ces canaux profonds on est très frappé de la couleur d’un noire intense, ressemblant à un vernis que présentent ces rochers toujours immergés pendant

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(<sup>1</sup>) Collected by Sir William Willcocks.

(<sup>2</sup>) Collected by Dr. W. F. Hume, Egyptian Geological Survey.

(<sup>3</sup>) April 1904 and March 1905.

(<sup>4</sup>) RUSSEGGER quoted by Walther in “Die Denudation in der Wuste.” Leipzig, 1891, p. 453.

(<sup>5</sup>) DE ROZIERE, “Description de l’Egypte.” 2nd Edition. Tome XXI, Paris 1826, p. 242.

les hautes eaux. On croirait naviguer au milieu d'énormes entassements d'une houille très foncée et très luisante." (¹)

"At the cataracts of the great rivers Orinoco, Nile and Congo, the syenitic rocks are coated by a black substance appearing as if they had been polished with plumbago." (²)

As will be seen from the last quotation this blackening of the rocks is not peculiar to the Nile; it is stated by Schweinfurth (³) to occur also on the Niger; it has been observed by Comstock at the rapids of the Tocantins river, Brazil, (⁴) and also in South America by Humboldt (⁵) and by Boussingault (⁶); by Pechuel-Lösche (⁷) on the Kiulu, and by Wissmann (⁸) on the Quige.

Darwin observed a similar phenomenon on the granitic rocks of the coast of Brazil near Bahia, though in this case the colour was brown and not black (²).

Specimens of garnetiferous gneiss (⁹) from the Third Cataract, and of a highly quartzose granite from a boulder found by the writer in the bed of the Nile at Shellal also show a brown and not a black film. In both these cases the rock is only slightly polished, and the browning is not limited to the surface but extends inwards for several millimetres.

Ball, describing a similar brown coloration on some specimens of syenite-porphyry from Semna, writes: "The exposed surfaces are of a rusty brown; and where below the high Nile level, they are polished so as to give the rock the appearance of 'eisenkiesel.' The brown skin penetrates to a depth of about one centimetre, the limit between it and the normal grey rock being very sharply defined (⁹)."

One of the best specimens of a black film examined was from the inside of a stone water tank found on the top of Gebel Geili in the Sudan. This tank which is probably of ancient Egyptian date is made of dolerite and is only filled during the rainy season and then with rain water which only travels a very few yards before reaching the tank. The film which is a dense mat-black is found on the inner surface of the

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(¹) LORTET ET HUGOUNENQ. "Comptes Rendus." No. 19, (12 mai 1902).

(²) C. DARWIN. "Voyage of the Beagle." London 1901, p. 12.

(³) LORTET ET HUGOUNENQ. Quoted in "Comptes Rendus." No. 19.

(⁴) T. B. COMSTOCK. Trans. American Institute of Mining Engineers, Lake Superior Meeting, Sept. 1904.

(⁵) A. VON HUMBOLDT. Quoted by Walther in "Die Denudation in der Wuste."

(⁶) M. BOUSSIGAULT. "Annales de Chemie et Physique". 5th Series, Tome XXVII, 1882, p. 289.

(⁷) Quoted by Walther in "Die Denudation in der Wuste."

(⁸) Collected by Dr. W. F. Hume, Egyptian Geological Survey.

(⁹) The Semna Cataract." DR. JOHN BALL. Quart. Journal Geological Society, 1903, Vol. LIX.

tank up to a height of about four feet, which is the height to which the tank is periodically filled. (¹)

All the films hitherto described have been on crystalline rocks, and it is on these rocks that the blackening ordinarily occurs. Two specimens, however, on limestone have recently been examined. One of these is from Ras-el-Kanais on the sea-coast west of Alexandria. The limestone here is soft and friable and the blackening occurs only about the tide mark, and neither below low-water nor above high-water level. Owing to the softness of the stone the surface of the rock is neither smoothed nor polished but very irregular, and there is no polishing on the film. (²)

The second specimen was from hard bands of nummulitic limestone outcropping and slightly projecting from the base of the cliffs about  $1\frac{1}{2}$  kilometres south-west of the village of Seraria, near Samalut, Upper Egypt. These beds of limestone are only separated from the river by a very narrow strip of cultivation and are probably under water every autumn except in years of very low flood. The film is black and polished. (³)

Having once remarked the blackened rocks of the cataract region at Aswan it is difficult not to notice also that many rocks away from the river have also a blackened surface. Thus the cliffs on either side of the valley that serves as a road between Aswan and Shellal, the limestone, sandstone and granite cliffs, respectively between Cairo and Korosko, that shut in the Nile valley, but do not come down to the water-edge, as well as many of the rocks and stones in the desert, are frequently brown or black on the upper surface.

This desert colouring has often been described. Zittel writes: "In the Libyan desert the upper surface of the light-coloured varieties of sandstone takes on a more or less intense brown colour, sometimes a complete black so that the Hammada (⁴) near Regenfeld (⁵) conveys the impression of being strewn with blocks of basalt or lava." (⁶)

Walther says: "As characteristic as the trace of the sand blast is the brown surface-colouring which is shown by many stones and rocks in

(¹) Sample collected and description furnished by T. Barron, F.G.S., Egyptian Geological Survey.

(²) Sample collected and description furnished by F. Hughes, Chemist, Khedivial Agricultural Society, Cairo.

(³) Sample collected and description furnished by H. J. L. Beadnell, F.G.S. Egyptian Geological Survey.

(⁴) The hard stony floor of the desert.

(⁵) South-west of Dakhla Oasis.

(⁶) "Palaeontographica." Vol. XXX. 3rd Edition. KARL A. ZITTEL, Cassel, 1883 p. 58-59.

the desert. The light-brown to dark-brown or even black colour is found on limestone as well as on siliceous rocks, it is formed in a relatively short time and must be regarded as a true desert appearance. (¹)

Overweg and Wheeler are both quoted by Walther to the same effect. The former says: "Between the Wadi el Hessi and the Wadi el Shiati (south of the Tripolitan Hammada) is a region of pitch-black rock. The rock is a sandstone, in part permeated by iron ore and then completely black or brown, in part snow white and only on the surface exposed to the air covered with a thin shining crust. (²)

Wheeler, writing of the Californian desert says: "It is remarkable that over wide stretches, rocks and rolled material are coloured black on the upper surface just as though they were coated with a black varnish." (²)

Blake, referring also to the same desert regions of the south-west portion of the United States, says: "Travellers can hardly fail to note that most of the rocky outcrops of the harder rocks have a uniform prevailing blackness of the surface in strong contrast with the normal colour of the interior of the rock when freshly broken. (³)"

"The pebble-covered plains which extend over many hundred square miles in the northern arid regions of South Australia and in Central Australia," according to Moulden "present similar phenomena." (⁴)

Obrutschew mentions the occurrence of similar films in the deserts of Central Asia (⁵) and G. Linck describes films seen in the Nubian desert between Wadi-Halfa and Abu Hamed (⁵).

Captain Lyons, describing a layer of flints 8 to 12 feet deep that covers the limestone surface of the desert three hours west of Girga, Upper Egypt, mentions that "while the topmost layer is... blackened by exposure, the lower ones... usually... show no signs of blackening." (⁶)

Ball and Beadnell refer to a similar blackening noticed on their journey from the Nile valley to the Baharia Oasis, as follows: "The plateau rock...is a hard, white limestone. Just beyond the dunes this rock is very siliceous, the exposed surface showing a smoky black colour ; the

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(¹) "Die Denudation in der Wüste." J. WALThER, Leipzig, 1891 p. 453.

(²) Quoted by Walther in "Die Denudation in der Wüste."

(³) W. P. BLAKE. Trans. American Institute of Mining Engineers, Lake Superior Meeting, Sept. 1904.

(⁴) T. C. MOULDEN. Trans. American Institute of Mining Engineers, Lake Superior Meeting, Sep. 1904.

(⁵) Quoted by Von G. C. Du Bois in Tschernak's Min. u. Pet. Mittel, Vol. XXII, Section I, Vienna 1903.

(⁶) "Stratigraphy and Physiography of the Libyan Desert." CAPT. H. G. LYONS, R.E., Quart. Journ. Geol. Soc. Nov 1894.

rock is, however, quite white on fracture. The chalk forming the cliffs weathers in places to a smoky black colour.”<sup>(1)</sup>

Du Bois, writing on films occurring at Surinam, in Dutch Guiana, summarizes most of the published references to similar phenomena.<sup>(2)</sup>

The above quotations will serve to show how universally distributed this colouring is in the desert.

There are therefore two classes of blackening: one of the rocks in the river channel and the other of the rocks and stones in the desert; and the first question that naturally presents itself is whether the two phenomena are identical, or if not identical, whether they have anything in common either in composition or mode of formation.

Walther is of opinion that the two are quite distinct, for he writes: “Certain black films which form on the banks<sup>(4)</sup> of tropical rivers should not be associated with the films of the desert as these latter are produced entirely without the aid of tropical climate or flowing water.”<sup>(3)</sup>

“The appearances have fundamental differences and must not be confounded with one another.”<sup>(3)</sup>

“The similar films formed on the banks<sup>(4)</sup> of tropical rivers are without significance in connection with the widely distributed phenomenon on the waterless desert.<sup>(3)</sup>”

With a view to discovering anything that might throw additional light on the composition or mode of formation of the river film, the rocks in the river channel at Aswan, Shellal and Kalabsha, and from Kalabsha to Korosko were carefully examined, and since it was thought possible that the desert blackening might have some bearing upon the question, many of the cliffs from Cairo to Korosko, near the river, but not actually washed by the water, were also inspected. The results of this examination will now be given in detail.

The rocks forming the cliffs of the Nile valley are mainly of three kinds namely limestone, sandstone and crystalline igneous rocks.

The limestone extends the whole distance between Cairo and Esna, a little south of which the sandstone begins, and at Silsila, some 70 kilometres before reaching Aswan, are the sandstone quarries used so largely by the ancient Egyptians.

The crystalline rocks which are first met with at Aswan extend as far as Shellal. Between Shellal and Kalabsha there are both sandstone and crystalline rocks, but at Kalabsha gorge the rocks are again wholly

(1) “Baharia Oasis.” BALL and BEADNELL. Cairo, 1903, pp. 28 and 34.

(2) Von G. C. Du Bois, Tschermak’s Min. u. Pet. Mittel Vol. XXII Section I, Vienna, 1903.

(3) “Die Denudation in der Wüste”. J. WALThER, Leipzig, 1891 p. 453–461.

(4) i. e. rocky banks.

crystalline, after which all through Nubia until Wadi Halfa is reached there is nothing but sandstone. After the second cataract, however, in the schistose series near Akasha, marble bands are prominently developed similar bands being found also near the third and fourth cataracts. In the Amara cataract region the more prominent hills are composed of dolomite.<sup>(1)</sup> The rocks of the second and subsequent cataracts are crystalline.

#### DESERT FILM.

##### Limestone

At Helwan, near Cairo, the surfaces of the limestone hills are sombre and dark, which is due to the innumerable fragments of hard siliceous material splintered by weathering that cover the sides of the hills and the tops of the plateaux; all these fragments are more or less coloured, the colour varying from a light-brown to a deep-black. Any flints are also brown or black. These latter, however, are not very numerous except on the south-east side of the town where the sandy surface of the desert is in places strewn with flints and pieces of silicified wood which are all dark-coloured, the flints as a rule being quite black. Both the upper and under sides of the flints are coloured, but the coloration of the former is generally black, while that of the latter is sometimes only reddish-brown. Side by side with the flints are white quartz pebbles without any surface coloration whatever, and others of a very light yellow shade with only a trace of a coloured film.

The flints are all uniformly coloured on any one surface. This is also the case with the majority of the siliceous limestone fragments which are sometimes of a smoky grey colour and sometimes light brown but in other instances these fragments are partly brown and partly deep-black. Where the colour is uniform in tint the stone is uniform in composition, but where the stone is coloured unequally the black or darker coloured portions are harder and more siliceous than the rest. This peculiar patchy coloration has all the appearance of being a definite black layer several millimetres in thickness once existing as a vein in the rock and now partly exposed by the splitting and splintering action of the weather, but this, however, is not the case. There is certainly a vein of different material, but it is not black, being simply a layer of the limestone more siliceous than the rest, and it is the edges and the top of this harder layer that have blackened where exposed, and this blackening, although apparently extending into the interior of the stone, is merely a film on the surface.

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(1) Communicated by Dr. W. F. Hume, of the Egyptian Geological Survey.

The step pyramid at Saqqara, the three large and the various small pyramids of Giza, all show a well-defined browning of the outer surface. That part of the casing of the second pyramid which still remains is sensibly browner than the rest of the surface of the pyramid from which the coating has been removed.

Walther, referring to the great pyramid, writes: "The rock squares on the summit of the pyramid of Cheops show the beginning of the browning, as also the wide galleries at Tura, out of whose material the pyramids were built, and one finds to-day the brown films on surfaces which still carry the traces of the old Egyptian chisel marks." (1)

The material of the Saqqara pyramid is a yellowish, somewhat sandy limestone, while the limestone of the Giza pyramids is white and nummulitic. In some cases the nummulites have become quite black while the stone in which they are embedded is only brown. In the majority of cases, however, the nummulites and other fossils are a lighter shade than the rest of the stone.

Although the browning is more pronounced on the outside, it is present also on the less-exposed surfaces, as in the cracks and crevices between the stones, and even several metres down the open passages, such as that in the third pyramid at Giza.

In some cases the colour is largely removed by washing with water and a stiff brush, but in other instances such washing has very little effect. Very little sand or dust can be seen on the surface of the stones even when they are examined by the aid of a lens. The hard limestone of the pyramid plateau is generally of a cement colour with a brownish tint in places.

The cliffs at Thebes, although limestone, are by no means white even in the glare of the mid-day sun; the face of the cliffs is as a rule light-brown to reddish-brown, the tops and corner slopes dark-brown to black and the large boulders as well as the small stones and flints that strew the valley, are all more or less blackened on the outer surface. The light brown coating penetrates into all cracks and fissures and spaces between the bedding planes.

In places where there are mounds of earth and modern Arab dwellings at the foot of the cliffs, the face of the rock, when carefully examined, shows a certain amount of extraneous matter in fine particles adhering to the surface, more particularly in the crevices and depressions. This adherent material appears to be simply dust blown on to the surface from the remains of the mud huts forming the mounds: clayey matter,

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(1) "Die Denudation in der Wüste" WALThER Leipzig, 1891.

small sand grains and tiny particles of straw can all be detected. This dust can be readily removed by washing with water and a stiff brush, leaving the limestone white and unaltered underneath. The light-brown and reddish-brown coating can also be partly removed by washing; in some cases the original white stone is exposed below, in other cases small dendritic markings of manganese dioxide are found, while in many instances a slight reddish coloration still remains.

The boulders, which are very dark-coloured when seen from a distance, are found on closer examination to consist of a dense semi-crystalline limestone very different from that of the cliffs, and are not uniformly blackened even on the upper surface, but exhibit a sort of black excrescence in patches. This excrescence consists of fossils and flinty masses embedded in the limestone, and these have become blackened when exposed.

The greater number of the flints examined were light-coloured internally, some few, however, were dark, and many of both the light and dark varieties were coated on the outside with a white siliceous material.

On both light and dark-coloured specimens, and whether possessing the white siliceous covering or not, there is almost invariably a reddish-brown to black patina.

Walther says: "the well-known white decomposition rinds of flints do not colour either brown or black,"<sup>(1)</sup> but certainly in the case of the flints from Thebes, this does not hold true, and the blackening is very marked even where the "decomposition rind" exists; this is left white and unaltered when the coloured film is removed by acid.

**Sandstone.**

The most remarkable feature of the Nubian sandstone from Kalabsha to Korosko as seen from the river is its dark-coloured upper surface. This is due to the fact that the tops of the cliffs are as a rule covered with a black or purplish-black layer sometimes two centimetres or more in thickness, the slopes and foot of the cliffs also being strewn with broken fragments of this same material. On the face of many of the cliffs there are dark-coloured bands of various degrees of thickness, together with round or oval black markings varying in size from a mere speck to about a centimetre in diameter. Some of the cliffs, as also some of the loose masses of rock at the bottom, show in addition a slight irregularly distributed black coloration which occurs in patches and which is never found uniformly covering the whole exposed surface of any one block.

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(1) "Die Denudation in der Wüste." J. WALThER, Leipzig, 1891 p. 453. 461.

One peculiar feature of the Nubian sandstone at Korosko is the great number of hard, more or less spherical, dark-coloured masses of various sizes that occur scattered about on the surface. These are the “volcanic bombs” (<sup>1</sup>) of Baker and the “black blisters which increase in size and form eventually round hollow black balls” (<sup>2</sup>) mentioned by Willcocks.

They are, however, simply concretions consisting of a sandstone core round which a thick mangano-ferruginous envelope has formed, and are not hollow in their original condition. The dark-coloured crust of the Nubian Sandstone is a hard, resistant ferruginous layer, containing varying amounts of oxide of manganese, which has been left exposed by the softer sandstone, which doubtless at one time covered it, having weathered away. It is in no sense a desert film, and the phenomena described by Zittel and Overweg already quoted (<sup>3</sup>) appear to be something quite different.

Some of the dark-coloured bands on the face of the cliff are of this same resistant layer, but others are much less definite, and contain a much smaller proportion of oxide of iron and more oxide of manganese: the small round and oval markings are also largely oxide of manganese. None of these are desert phenomena; the slight, irregularly distributed black coloration at the sides of the cliffs and on the loose blocks at their foot resembles very much a true desert blackening, and it is impossible to say definitely in every instance whether such is the case or not. It is believed, however, that in many instances it is no true desert film, but a slight accumulation of iron and manganese oxides that already existed in the sandstone, and has simply been exposed. In favour of this view is the fact that a similar coloration can be found in the joints between two separate blocks of stone even where the joint occurs at the back of the block.

The sandstone cliffs therefore from Kalabsha to Korosko along the river front, show no well-defined desert blackening such as that already described on the siliceous limestone and flints at Helwan, and on the fossils and flints in the limestone at Thebes. It is not stated that no such film exists on the Nubian sandstone, but merely that on the cliffs examined no instance could be found of a clearly marked, definite and unmistakeable desert coloration. The formation of such a film would naturally be precluded in those places where the thick, ferruginous crust exists, and where there is no crust the sandstone is so soft and friable that the surface would probably weather off before the film had time to form.

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(1) “Nile Tributaries of Abyssinia,” SIR SAMUEL BAKER, London, 1872, p. 5

(2) “Egyptian Irrigation,” SIR W. WILLCOCKS, 2nd Edition, 1899 p. 5

(3) pages 5 and 6.

Crystalline  
Rocks

The granite on the Aswan-Shellal road looks almost black when seen from a distance, which is partly due to a slight dull-black surface coloration of the granite, and partly to dykes of darker intruded rocks; these darker masses are as a rule split and cracked in every direction, and the small flakes and fragments that strew the slopes of the cliffs enhance the general dark aspect. The granite cliffs bordering the river at Shellal and Kalabsha, but far above any high-flood level of historic times, exhibit also more or less irregularly a slight dull-black surface, and in most cases, both here and on the cliffs of the Aswan-Shellal road, where this blackening exists, the granite is much disintegrated. The black coloration cannot be washed or brushed off.

Summary

DESERT FILM.—The several varieties of coloration on rocks and stones in the desert already described may now be briefly summarised : they are :—

(1) The black or purplish-black colour of the surface of much of the sandstone in Nubia on the cliffs near the river.

This is a hard, resistant mangano-ferruginous layer probably previously existing in the rock and now exposed on account of the softer sandstone once covering it having weathered away, and is in no way a desert film although frequently mistaken for such.

Even Zittel (<sup>1</sup>) does not seem to distinguish between the true film which is a mere patina on the surface of the stone and a distinct layer or crust which although similar in composition is very different in origin.

The composition is very variable; it is, however, essentially a mixture of iron and manganese oxides in varying proportions, but containing also other ingredients such as silica, alumina, lime, etc.

The following is an analysis of such a layer examined by Wingard (<sup>1</sup>).

Manganese dioxide	...	...	...	...	30.57	%
Carbon dioxide	...	...	...	...	4.06	„
Barium monoxide	...	...	...	...	4.89	„
Alumina	...	...	...	...	8.91	„
Iron oxide	...	...	...	...	36.86	„
Silica	...	...	...	...	8.64	„
Water	...	...	...	...	5.90	„
Phosphoric acid	...	...	...	...	0.25	„
					99.88	„

(<sup>1</sup>) "Palaeontographica," K. A. ZITTEL. Vol. XXX 3rd Edition, Cassel, 1883 p. 58-59

(2) The brown coloration of the surface of the pyramids at Saqqara and Giza, of the limestone at Helwan and Thebes, and of the granite and other crystalline rocks on the desert cliffs near Aswan.

This is largely a genuine desert coloration, the colour being in great part cemented fast to the stones; in some cases, however, the colour is intensified by the presence of dust or other loosely adherent material.

(3) The brown to black coloration on flints and flinty material.

This is a genuine desert phenomenon and no part of the colour is in any way due to dust or dirt on the surface.

The composition and mode of formation of the desert film have been dealt with at length by Walther.

Composition  
and Mode of  
Formation

Concerning the composition of the film he points out that almost all mixtures of iron and manganese oxides are found from the nearly pure iron oxide to the nearly pure manganese oxide and he records also the occurrence of traces of nickel found by Wheeler in some films from the Californian desert, 8% of cobalt found by Sickenerger in the Dakhla Oasis films, and 2.5% of phosphoric acid found by Piccard and Sickenerger in the films from some Egyptian limestones.

Concerning the formation of the film he writes :—

“ The brown protecting film is an appearance produced by the desert climate. It depends upon the action of the sun and a certain silica content of the rock. The colouring of manganese and iron is not derived from the rock, for if the latter were the case only rocks rich in manganese and iron would be brown, and it would be impossible for snow-white sandstone, limestone or flint to be coloured.”<sup>(1)</sup>

Wheeler, however, is quoted by this same writer to the opposite effect. Writing of the film on the rocks of the Californian desert, Wheeler says : “ the manganese content of the rock appears to have taken part in its formation, for it is just the granites which have as a constituent an amethyst-coloured quartz which show the black coating most.”<sup>(1)</sup>

Walther accounts for the presence of iron and manganese compounds in the film by saying: “ the clay dust which often fills the desert air and which is driven by the wind against all rocks, possibly contains manganese and iron and so may form the coloured salts.”<sup>(1)</sup>

In a later book Walther, explaining in detail the manner in which he believes the film to have been formed, writes : “ the same forces come into play which in other rocks produce films of easily soluble salts, namely traces of rock humidity and intense sun heat”.

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(1) “Die Denudation in der Wüste.” J. WALThER, Leipzig, 1891, p. 453-461.

“ All the rocks in Egypt are more or less porous and take up a certain amount of water when moistened by dew or rain. All rocks in Egypt in addition contain traces of easily soluble salts especially common salt. These chloride solutions under certain conditions take up iron and manganese salts which were either already in the rock or have been blown on to the moist rocks in finest particles of dust.”<sup>(1)</sup>

“ The carbonic acid and phosphoric acid derived from the fossils also play their part as a means of solution.

“ When a rock which is permeated by such solutions is heated and dried the solutions are brought to the surface by capillary attraction and the iron and manganese salts dry and form a delicate covering.

“ The silica in crystalline rocks and the phosphoric acid in the limestones have such an affinity for freshly deposited iron and manganese oxides that at the place of contact chemical combination takes place which cements the oxides fast while the separated chlorides are blown away by the wind.”<sup>(1)</sup>

Merrill describes the film from some quartzitic boulders found in the Serrier desert in Utah as: “a thin dark varnish-like coating which consists largely of oxides of iron and manganese though a slight amount of organic matter is present.”<sup>(2)</sup>

Blake gives the composition of the film as oxide of iron or manganese or both, but makes no mention of any other constituent, and adds that: “in general ferrous salts are changed to the insoluble ferric form under the influence of the sun’s rays,”<sup>(3)</sup> he states that “the coloration proceeds from within the rock rather than from without”<sup>(3)</sup> and ascribes its formation to “an osmotic flow, a kind of rock transpiration tending upwards and outwards to supply the excessive evaporation under hot arid conditions.”<sup>(3)</sup>

Blake states too, that the phenomenon is closely allied to the formation of caliche and to the incrustation of salt and of other saline soluble compounds generally called “alkali.” This view is also held by Sickenberger who writes: “as to the origin of the film the occurrence is the same as that so often seen in Egypt which brings about the formation of the salt crust and gypsum crystals of the sand-covered salines.”<sup>(4)</sup>

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(1) Das Gesetz der Wüstenbildung. J. WALThER Berlin, 1900, p. 22-24.

(2) “Rocks, Rock-Weathering and Soils,” by J. P. MERRIL, New York, 1897, p.256

(3) W. P. BLAKE. Trans. American Institute of Mining Engineers, Lake Superior Meeting, September 1904.

(4) Manuscript report by Prof. E. SICKENBERGER kindly lent to the writer by Prof. Walther.

Blake, however, finds difficulty with regard to the origin of the colouring on loose pebbles and says: "We should expect to find a greater diversity of colouring than actually exists if we consider the mass of the pebble alone as the source of the flow, and we would also expect to find a variation of colouring and of intensity corresponding to the varying degrees of hardness and of composition." <sup>(1)</sup> He states very definitely that "the mass of each pebble is not sufficient to yield an amount of colouring solution adequate to produce the change" <sup>(1)</sup> and to explain the formation of the film in such cases he assumes that "there is an osmotic flow from the subjacent earth to the pebbles, and that the solutions though small in volume and weak in composition are uniform in nature, and are finally concentrated at the exposed surfaces." <sup>(1)</sup>

Fraas states that in the formation of films weathering takes place from the centre of the rock, which becomes softer, towards the outside, which gradually becomes harder." <sup>(2)</sup>

Linck considers the films on desert rocks to be a product of chemical weathering which takes place under the special conditions consequent upon a tropical desert climate, and he divides the stages of the film formation into four phases, namely :—

- (1) Impregnation of the upper surface of the rock with dew.
- (2) Solution and decomposition of the rock minerals aided by the high desert temperature.
- (3) Oxidation of the solution by the help of various constituents of the air dissolved by the water.
- (4) Drying and crystallisation of the new formed combinations by means of the sun's heat. <sup>(2)</sup>

Obrutschew believes the film to be produced at the expense of the iron and silica content of the rocks. <sup>(2)</sup>

Du Bois is of opinion that there is some relation between the ozone content of the desert air and film formation, and he quotes Walther to the same effect <sup>(2)</sup>.

The various quotations just given summarize all that can be found published concerning the composition and formation of the desert film.

With regard to the composition, most of the writers have omitted all mention of any constituents other than iron and manganese oxides ;

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(1) W. P. BLAKE. Trans. American Institute of Mining Engineers, Lake Superior Meeting, September, 1904.

(2) Quoted by Von G. C. Du Bois, Tschermake's Min. u. Pet. Mittel, Vol. XXII, Section I, Vienna, 1902.

nickel and cobalt however are each given once, and phosphoric acid is recorded on films from Egyptian limestone.

As to the origin of the film there are two main theories, namely that of Walther in which water in the form of dew or rain enters the rock, dissolves out sodium chloride, and in the case of limestone and fossils, also carbon dioxide and phosphoric acid, and then the solution thus formed, after further taking up iron and manganese compounds, either from the interior of the rock itself or from adherent particles of dust, is brought to the surface by capillary attraction and there evaporated, leaving the iron and manganese behind as insoluble oxides.

The second theory, that of Blake, apparently supposes that the iron and manganese salts are already in solution in the pores of the rock or in the ground immediately below, and are simply drawn to the surface and there evaporated, the solvent action of rain however not being wholly excluded.

Before being in a position to seriously discuss the question at all a more careful and detailed examination of specimens than had hitherto been attempted was necessary, and this was therefore made.

The film cannot be scraped or rubbed off in any way, but can be easily removed by means of strong hydrochloric acid in which it is readily soluble in the cold, forming a clear, dark-brown solution which becomes lighter coloured on heating.

Since the film cannot be separated mechanically and weighed it is difficult to determine its percentage composition. By adding together the weight of the various ingredients found and using this figure as the total weight of the film a percentage composition of some sort can be calculated, but this method assumes that everything present has been determined, and entirely ignores such a very probable constituent as water of hydration, which, owing to the nature of the sample, it is impossible to determine. To remove the film by acid and to weigh it by difference, although this has been the method followed in this laboratory, is not wholly satisfactory even with such a material as flint, and cannot be relied upon at all in the case of limestone, even though the limestone be siliceous.

However as no useful purpose was to be served by quantitative results, since the limits of variation are very wide, most of the analyses were qualitative only, in order to ascertain what constituents were present in each case and whether any substance could be detected in the film that did not occur in the rock underneath.

Several hundreds of films were examined altogether but the following tables summarizes the composition of the most typical :—

CONSTITUENTS	SILICEOUS LIMESTONE		FLINTS		Crystalline rock	Silicified wood
	Helwan	Thebes	Helwan	Thebes	Aswan	Helwan
Silica.....	nil	nil	nil	nil	nil	nil
Oxide of iron .....	present	present	present	present	present	present
Alumina.....	»	»	»	»	»	»
Oxide of manganese..	»	»	»	»	»	»
Lime.....	»	»	»	»	»	»
Magnesia.....	nil	nil	»	nil	nil	nil
Phosphoric acid.....	present	present	»	present	present	present
Sulphuric acid.....	»	»	»	nil	»	»
Potash .....	»	»	»	present	»	»

In addition to hydrochloric acid the action of nitric acid was also tried. With boiling nitric acid the solution is only slightly coloured, and in the cold usually not coloured at all. This apparently colourless solution, however, contains both iron and manganese compounds, as also does the solution produced by the boiling acid. All the other ingredients of the film are present also in each case.

The solubility of the film in water was next ascertained. After carefully washing the surface of a number of flints with water and a stiff brush and rinsing in distilled water they were boiled in distilled water for several hours then allowed to stand overnight, the water decanted off, evaporated to small bulk and tested. The solution thus obtained was quite colourless and neither iron nor manganese could be detected, but compounds of aluminium, calcium, magnesium, and potash, together with chloride, sulphate and phosphate were present.

An attempt was then made to determine these ingredients quantitatively in the water solution.

Two separate lots of flints were treated as described above, the details of the weight of the samples before and after treatment being as follows :—

	1 grams	2 grams
Weight of flints before the action of water.....	871.7	872.5
Weight of flints after the action of water.....	871.5	872.3
Weight of material removed by the water .....	0.2	0.2

The samples, however, being too heavy for a delicate chemical balance could not be weighed with any great degree of accuracy.

In No. 1 the aluminium, calcium and magnesium were separately precipitated, but both the aluminium and magnesium were present in too small a quantity to be determined quantitatively ; the calcium, however, was weighed and found to amount to 5·04 % calculated as CaO.

In No. 2 it was found that the phosphate, sulphate, chloride and potash were each present in too small an amount to weigh.

The presence of phosphoric acid in most if not all films, and the occurrence of alumina, lime, magnesia, potash and sulphuric acid seems hitherto to have escaped notice.

The composition of the film having been determined, the origin of the constituents becomes the next problem.

Do the various ingredients forming the film come from within the rock itself or from without ? Walther says largely from within, but supplemented in certain cases by constituents derived from the desert dust. Walther's assumption, however, that "snow-white sandstone, limestone, and flint" never contain manganese, cannot be endorsed. There may be instances where such is the case, but in all samples of sandstone, limestone and flint examined in this laboratory, both iron and manganese have been found, though sometimes only in traces. Even some white quartz pebbles contained sufficient manganese to give a slight green colour when fused with oxidizing mixture.

Walther's conclusion therefore that the manganese and iron of the film cannot come from the rock itself is not endorsed by the experiments made.

Blake also says that usually the constituents of the film are derived from the rock, but that in the case of loose-lying pebbles the stones themselves do not contain sufficient of the colouring material necessary to produce the film, and then the earth immediately below furnishes

the requisite supply. No figures or data, however, are given to prove that the film even on small pebbles ever contains ingredients in greater quantity than could have been supplied from the stones themselves. In connection with this point three specimens of film-covered stone were well washed with water and a stiff brush, rinsed in distilled water, and again dried and weighed and then treated with acid. The weights of the stones before and after treatment and the weights of the films removed were as follows:—

NATURE OF SAMPLE	A FLINT	B FINE-GRAINED RED GRANITE	C SILICIFIED WOOD
	grams	grams	grams
Weight before treatment with acid .....	58.3474	348.00	136.2932
Weight after treatment with acid.	58.3130	347.75	136.2058
Weight of film removed by the acid .....	0.0344	0.25	0.0874

The phosphoric acid was then determined in these film solutions. Phosphoric acid was chosen because it is a characteristic ingredient and less likely to be so widely distributed as iron and manganese compounds. The following results were obtained :—

SAMPLE	A	B	C
	grams	grams	grams
Weight of $P_2O_5$ in film.....	0.00384	0.00223	0.00644
Percent. of $P_2O_5$ in film .....	% 11.12	% 0.89	% 14.73
Percent. of $P_2O_5$ calculated on original stone .....	% 0.006	% 0.0006	% 0.004

Although the percentage of the phosphoric acid in the film is high, the actual amount present is very small indeed, and represents only a trace when calculated as a percentage on the original stone.

Various other determinations of phosphoric acid were also made with the following results :—

SAMPLE	P <sub>2</sub> O <sub>5</sub>
Flint with slight brown film .....	% 0.03
Nummulite: no film .....	Trace
Flint with considerable black film .....	0.02
Interior only of flint.....	0.01
Interior of silicified wood.....	Trace

In none of the cases examined, therefore, can it be said that the phosphoric acid is in so large a quantity in the film that it could not have been derived wholly from the stone itself.

Merril<sup>(1)</sup> gives the following table showing the phosphoric acid content of various rocks :—

ROCK.	PHOSPHORIC ACID (P <sub>2</sub> O <sub>5</sub> )	
	MINIMUM	MAXIMUM
Granite .....	% 0.07	% 0.25
Diorite .....	0.18	1.06
Basalt .....	0.03	1.18
Limestone .....	0.06	10.00
Shale.....	0.02	0.25
Sandstone .....	0.00	0.1

With regard to the other constituents of the film the case is very similar, and in the hundreds of samples examined there was not a single instance of anything being found in the film that was not also present in the rock below.

(1) "Rocks, Rock-Weathering and Soils." G. P. MERRIL, New York, 1897, pp. 6-8.

In the case of the film upon flints, for example, all the ingredients composing the film are such as occur naturally in the flints themselves. The following analyses of flints may be quoted:—

**Flint.**

CONSTITUENTS	1	2	3	4	5
	EXTERIOR	INTERIOR	EXTERIOR	INTERIOR	INTERIOR
Silica .....	88.63	97.01	97.91	99.18	96.31
Alumina .....	..	..	..	..	0.30
Oxide of Iron .....	0.74	0.76	1.28	0.54	0.25
Lime .....	0.90	0.66	..	..	0.47
Potash .....	0.12	..	..	..	..
Soda .....	..	0.50	0.66	0.28	..
Phosphate of Lime.....	0.09	..	..	..	..
Carbonate of Lime.....	8.26	..	..	..	..
Carbonate of Magnesia ..	0.18	..	..	..	..
Water and Organic Matter.....	1.08	1.16	..	..	2.81
	100.00	100.09	99.85	100.00	100.14

These analyses, however, are all more or less incomplete, and although phosphoric acid is only given in one sample, and manganese is not mentioned at all, it is very probable indeed that traces at least of both these substances were present in every case. As already mentioned both manganese and phosphoric acid were found in all samples of Egyptian flints tested.

If, then, the film has originated wholly from within, to what is the decomposition of the rock due, and what has caused the separation and precipitation of the film constituents?

(<sup>1</sup>) VON DER MARCK. Quoted by Roth in "Allgemeine und Chemische Geologie," Berlin,

(<sup>2</sup>) 1879, vol. I., p. 95.

(<sup>3</sup>) FRISCH. Quoted by Roth in "Allgemeine und Chemische Geologie," Berlin, 1879,

(<sup>4</sup>) vol. I., p. 95.

(<sup>5</sup>) RICCIARDI. Quoted by Roth in "Allgemeine und Chemische Geologie," Berlin, 1879  
vol. II., p. 565.

The experiments of the Rogers Brothers in 1848,<sup>(1)</sup> of Richard Müller in 1877<sup>(2)</sup> and the more recent work of F. W. Clarke<sup>(3)</sup> all prove that even pure water partially decomposes many minerals and rocks. The Rogers Brothers and Müller also showed that the solvent action upon the rocks tested was much increased when the water contained carbon dioxide in solution.

Both these facts have been tested and confirmed in this laboratory, and the experiments will be described later.<sup>(4)</sup>

The amount of any given compound that will dissolve in water varies with the nature of the compound and the conditions under which solution takes place, increasing as a rule with increase of temperature, and increasing also when certain other bodies are present at the same time; the solubility of calcium sulphate for instance is much increased by the presence of sodium chloride, and that of calcium carbonate by the presence of either sodium chloride or sodium sulphate. Free phosphoric acid is also present, however, in a large number of cases, and this will materially aid any solvent action taking place. This phosphoric acid is derived from the decomposition of phosphates of iron, aluminium or calcium by means of water. On this action of water upon phosphates a considerable amount of work has been done from time to time and the results of this work have recently been summarized, and the work itself considerably extended by Cameron and Hurst<sup>(5)</sup> and Cameron and Seidell.<sup>(6)</sup>

"The phosphates of iron, aluminium and calcium are all substances which react with water or are hydrolyzed, yielding as one of the products of the reaction phosphoric acid and at the same time the hydroxide of the metal or possibly a basic phosphate. The solutions always contain free acid."<sup>(5)</sup>

The solutions thus formed are not, strictly speaking, solutions of the phosphates at all, but solutions of the decomposition products, and the phosphate itself is frequently present only in traces. The solubilities of ferric phosphate, aluminium phosphate and tri-calcium phosphate are all diminished by the presence of potassium chloride<sup>(5)</sup> and possibly therefore by sodium chloride also.

Carbon dioxide in the solution makes no appreciable difference in the extent to which ferric phosphate, aluminium phosphate or monocalcium

(1) American Journal of Science and Arts, 1818.

(2) Quoted in "Rocks, Rock-Weathering and Soils," by G.P. MERRIL, New York, 1897.

(3) Bulletin of the U.S. Geological Survey, No. 167.

(4) See page 36.

(5) Cameron and Hurst. Journal Amer. Chem. Soc., Vol. XXVI., No. 8.

(6) Cameron and Seidell. Journal Amer. Chem. Soc., Vol. XXVI., No. 11.

phosphate are soluble, but it increases the solubilities of both di-calcium and tri-calcium phosphate.<sup>(1)</sup> <sup>(2)</sup>

The temperature of the solutions, as would be expected, influences the solubilities of the various salts, and in each case a rise of temperature increases the solubility.<sup>(1)</sup> <sup>(2)</sup>

Not only, then, do all the film constituents occur in the rock or flint on which the film is found, but these constituents are all soluble to at least some slight extent in water, the solubility being increased in many instances by the presence of carbon dioxide, sodium chloride, phosphoric acid, etc.

Since in the case of limestone it appeared as though the coloration was darker where the rock was harder, several specimens were examined quantitatively for silica. The results obtained were:—

NATURE OF STONE	SILICA %
Fairly hard limestone from Helwan which only colours brown....	0.77
Very hard limestone from Helwan which colours black .....	21.25
Hard semi-crystalline limestone from Thebes which colours black.	59.50

This bears out Walther's statement that "the colour is much the darker the more the silica content of the rock."<sup>(3)</sup> Walther further says: "It is certain that the brown parts are harder and more resistant than the non-coloured parts, but it is doubtful whether this is cause or effect, the latter being thought to be the case."<sup>(3)</sup>

There can be little doubt, however, that the depth of the colour is dependent upon the amount of black oxide of manganese in the film, and that this is conditioned first by the manganese content of the rock, and secondly by the opportunities presented for the manganese salts to be brought to the surface and oxidized.

Du Bois believes that any chemical examination of the films must be unsatisfactory, first because the film is very thin and so intimately connected with the rock that it cannot be entirely separated, and secondly because some of the rock substance is likely to be included and so vitiate the analysis; he prefers, therefore, the microscopic examination of the films, and examined under the microscope sections of film-bearing laterites and other rocks from Surinam.<sup>(4)</sup>

(1) Cameron and Hurst. *Journal Amer. Chem. Soc.* Vol. XXVI., No. 8.

(2) Cameron and Seidell. *Journal Amer. Chem. Soc.*, Vol. XXVI., No. 11.

(3) "Die Denudation in Der Wüste." J. WALThER, Leipzig, 1891.

(4) Von G. C. Du Bois. *Tschermak's Min. u. Pet. Mittel*, Vol. XXII., Section I., Vienna, 1903.

